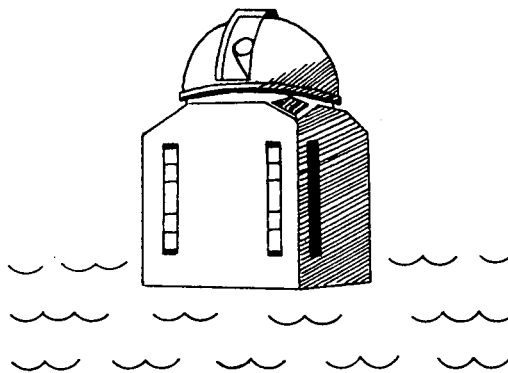
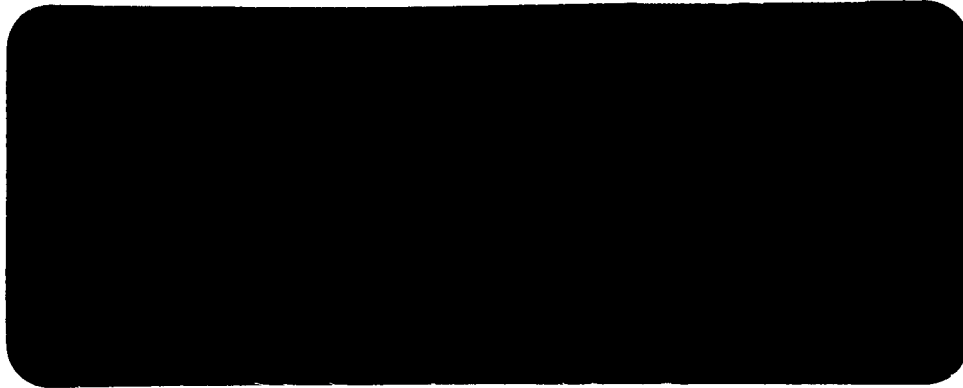


CALIFORNIA INSTITUTE OF TECHNOLOGY

BIG BEAR SOLAR OBSERVATORY

HALE OBSERVATORIES



N72-12629

(NASA-CR-123479) INTENSITY OSCILLATION IN
H ALPHA-FINE STRUCTURES A. Bhatnagar, et
al (Hale Observatories, Pasadena, Calif.)
[1971] 22 p CSCI 20F

Unclas
09585

FACILI

CR 123479
(NASA CR OR TMX OR AD NUMBER)

23
(CATEGORY)

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

G3/23

INTENSITY OSCILLATION
IN H α -FINE STRUCTURE

by

Arvind Bhatnagar and Katsuo Tanaka

BIG BEAR SOLAR OBSERVATORY, HALE OBSERVATORIES
CARNEGIE INSTITUTE OF WASHINGTON
CALIFORNIA INSTITUTE OF TECHNOLOGY

ABSTRACT

Using a new technique of directly measuring the intensity variation from the 16mm time-lapse filtergram movies taken in the blue wing and in the line center of $H\alpha$, we found periodic intensity oscillations in the center of $H\alpha$ -supergranulation network, in rosette centers and in plage granules. The oscillatory period of intensity in the network is of the order of 170 ± 44 seconds while in regions of stronger magnetic field, such as in plages and in rosettes, the period was found to be longer, on the order of 300 ± 50 seconds. It is suggested that observed intensity oscillation in the rosette center is related to the shooting out of dark mottles from rosettes. Oscillatory intensity fluctuations have been also observed in the sunspot umbra.

1. INTRODUCTION

The $H\alpha$ time lapse filtergram movies obtained in the line center and in the wing of $H\alpha$, show intensity fluctuations either due to the Doppler shift or due to the intrinsic brightness variation in plage regions. The movies obtained in the wings of $H\alpha$ -line show random motion of various dark mottles, both on the edges and inside of net work cells, due to Doppler shift and intensity variation. Intensity and velocity variations in various lines have been determined earlier by spectroscopic and spectroheliographic methods (Noyes and Leighton, 1963; Jensen and Orrall, 1963; Evans, et al., 1962). These results show periodic variation in intensity and velocity. Spectroscopic methods are limited to only one dimension, while the spectroheliographic method suffers from low time resolution, except for the recent work by Sheeley (1970) and Sheeley and Bhatnagar (1971). Quantitative determinations of the intensity and velocity fluctuations of individual fine structure seen on the high resolution $H\alpha$ time-lapse filtergram movies has not been hitherto done.

To obtain a quantitative estimate of these brightness fluctuations directly from the 16mm movies, we have used a very simple technique. A 16mm movies is projected on a photocell with a desired aperture, the output of which is connected to an amplifier and a recorder. By adjusting the rate of projection and the time constant of the recording system, it is possible to obtain good records of the intensity variation of individual fine structures on the sun without going through an elaborate procedure of using microphotometer for each frame of the movie. For this technique it is essential that

seeing and the telescope guiding should be especially good during the whole run. For this analysis we have used the filtergram movies obtained in the blue wing of $H\alpha$ ($H\alpha-0.5A$) and in the $H\alpha$ line center at the Big Bear Solar Observatory on March 29, 1971, showing pictures taken under extremely fine seeing and guiding conditions.

2. OBSERVATIONS AND RESULTS

The observations were made using the two 10"-telescopes in conjunction with two $H\alpha$ -filters (Halle type band pass of 0.5A) mounted on the same spar (Zirin, 1970). One of the filters was centered at the $H\alpha$ line center while the other at 0.5A in the blue wing of the $H\alpha$ -line ($H\alpha-0.5A$). Time lapse pictures were obtained at intervals of 10 seconds on Eastman Kodak SO-392 film. For this investigation, we have chosen the sequence of pictures obtained between 17.21 to 18.00 U.T. and others between 18.10 to 18.50 U.T. on March 29, 1971. The selection of these two sequences depended mainly on the seeing and guiding conditions during the run. One of the frames taken at ($H\alpha-0.5A$) is shown in Figure 1. The region covers two sunspots, a dark filament, a number of $H\alpha$ -rosettes, an arch filament system, and plage regions. This active region was at 20° S and 20° E from the central meridian.

Using the technique described earlier, we have measured the intensity oscillation directly from the 16mm time lapse movies inside the $H\alpha$ -supergranulation network, in the centers of rosettes, in plage granules, in sunspot umbra and in a blank region where no $H\alpha$ -structures were seen. We used a 2" arc

aperture in front of the photocell, thus our measurements refer to solar features on the order of 2" arc. Location of the measured places are shown in Figure 1. In Figure 2a is shown the intensity tracing made in the blank region, a on Figure 1. The tracing shows clearly that no brightness fluctuations are seen during the entire run and thus indicates that the sky transparency and filter transmission during the whole run remained constant. The results of the intensity oscillation measured at the locations shown in Figure 1 are summarized in the following:

A. Inside the Supergranulation Network

Five tracings were made inside the network, where no apparent fine dark mottles were seen, but only dark or bright small grains appeared. The location of the measured points are indicated in Figure 1 by corresponding letters in Figure 2, showing the intensity-time tracings. All of the 5 tracings show conspicuous intensity oscillations of fairly periodic nature. The average period obtained from each of the tracings was: 170 sec (b), 152 sec (c), 178 sec (d), 172 sec (e), and 177 sec (f). An average period obtained from all the intensity-time tracings is 170 ± 44 seconds, in H α -supergranulation network.

B. At the Centers of H α -Rosettes

On high resolution H α -wing pictures, the dark coarse mottles dissolve into fine dark elongated mottles and some form a small cluster of these features at the boundary of super-

granulation. In a cluster the dark elongated mottles radiate outward from a center, such a cluster of mottles is called by Beckers (1968) a "rosette". In this movie a number of round closed rosettes and some not so symmetrical open rosettes are seen, as indicated in Figure 1. On pictures at $H\alpha-0.5$, the radially oriented dark mottles in rosettes do not seem to extend inwards up to the center of the rosette and thus 4-5 arc seconds region appears free of dark mottles at the center. Such regions are known to be areas of enhanced longitudinal magnetic field. We measured the intensity fluctuations at the center of 5 rosettes, using a 2" arc aperture; 3 rosettes were closed round ones and two were partly open. The intensity-time tracings are shown in Figure 3. We see definitely that there is some oscillatory character in the intensity tracings. The observed average period of intensity oscillation in 3 closed rosettes was 384 sec (B^1) 289 sec (B) and 334 (C). But at the centers of 2 open rosettes, the period was shorter: 244 sec (A), 307 sec (D). (The letter (B^1) with a prime indicates the time interval at 17.21 to 18.00 U.T. Others refer to that of 18.10 to 18.50 U. T.) Assuming that both closed and open type rosettes refer to the same physical entity, we could take an average of all the periods, thus we see that intensity at the center of rosettes oscillates with a period of 312 ± 56 seconds. On some very good ($H\alpha-0.5A$) frames one could see fine bright granules at the center of rosettes. We believe that the observed oscillations are due to the brightness variations of these fine granules.

C. In Plage Granules

On high resolution pictures in ($H\alpha$ -0.5)A, plages dissolve into small granule elements or grains. On a time-lapse movie these small granules show conspicuous intensity fluctuations. We measured the intensity variation at 6 locations in the plage region. The location of the measured points are shown in Figure 1. Some of the intensity-time tracings made in the plage region are given in Figure 4. The average period of oscillation at 6 locations was: 292 sec (E), 313 sec (F), 297 sec (G), 259 sec (H), 266 sec (I) and 263 sec (J), or an average of all oscillatory periods in plages is 282 ± 49 seconds.

D. In the Sunspot Umbra

On the $H\alpha$ -0.5A movie, the sunspot umbra shows conspicuous brightness variation. The intensity fluctuation measured in the umbra (U) is shown in Figure 5. The intensity seems to oscillate with an average period at 190 ± 66 seconds. The oscillations seem to continue for 3 or 4 cycles with the same period and then change to another period. Bhatnagar (1971) has shown from magnetographic measurements that the amplitude of the oscillatory velocity field at photosphere level in sunspots is non-existent. Thus, it is likely that the observed oscillations are due to the intensity oscillations rather than due to velocity oscillations in the sunspot umbra. It is not confirmed whether these observed intensity oscillations in $H\alpha$ have any correlation with the calcium flashes observed in sunspot umbra by Beckers and Tallant (1969). The umbra under

high angular resolution in $H\alpha$ dissolves into small umbral granules (Figure 1), the observed oscillations seem to be due to the intensity fluctuation of these umbral granules.

3. VISIBILITY OF DARK MOTTLES IN ROSETTES AND CORRELATION WITH INTENSITY OSCILLATION

On high resolution time-lapse $H\alpha$ -wing movie, fine dark mottle structures in rosettes appear to shoot towards the outer boundary of a rosette. Beckers (1968) has estimated the birth rate of these fine dark mottles in rosettes and found 4 mottles per minute for each rosette. In order to find for a possible correlation with the shooting out of these dark mottles and the intensity oscillations at the center of a rosette, we have used the following method: we examined all frames taken every minute and assigned weights depending on the visibility of a dark mottle, ranging from 0 to 3, where 0 means no mottle seen at a certain location in a rosette, while 3 means maximum intensity and size of a mottle. Figure 6 shows rosette C and the variation in intensity, shape and size of dark mottles marked by arrows and indicated numbers, corresponding to numbers in Figure 7. An example of the plots showing the mottle visibility curves and the brightness oscillations at the center of rosette C are given in Figure 7. From these curves it appears that during the increasing phase in intensity, larger of mottles tend to attain their maximum visibility. However, it is difficult to find an exact one-to-one correspondence with the brightness oscillations at the rosette center

and the appearance of dark mottles in all cases. Even if the intensity oscillation at the center of rosettes is responsible for shooting out dark mottles, it is possible that due to the finite velocity of propagation the two phenomena may not be in phase.

From the visibility curves we derived the life time of dark mottles, defined as the time in minutes at half visibility. The average life time of dark fine mottles in rosettes is found to be about 6 minutes. Beckers (1968), Bray (1968) and Macris and Alissandrakis (1970) have obtained similar value for the life time of dark mottles. It is interesting to see that the period of the intensity oscillation at the rosette center (312 ± 56 sec) is of the same order of magnitude as the life time of dark mottles. It seems likely that the observed oscillations in the rosette center are connected with the appearance of dark mottles, which might be spicules seen on the disk. According to Parker's (1964) model of spicules, the horizontal and vertical motions in the photosphere leads to generation of sound waves; the propagation of which is more efficient in magnetic regions, thus the shocks formed by the propagation of motions in the lower density regions of the chromosphere are seen as spicules. The observed intensity oscillations in the rosette center may be a manifestation of the variation of pressure and density in the layers responsible for shooting out dark mottles. Thin dark elongated fibrils are seen near the boundary of H α -plage region; many observers have noticed conspicuous motion in these fibrils (Foukal, 1971). The observed intensity oscillations would cause pressure changes

near the roots of fibrils (Figure 1) and may be responsible for the observed motion in fibrils too.

4. DISCUSSION

The intensity oscillations measured directly from the 16mm time-lapse movie obtained in the blue wing of $H\alpha$ -line, do not uniquely indicate that whether the observed intensity variations are due to the velocity oscillations or due to intrinsic brightness variations or transverse oscillation of discrete magnetic features. We have tried to resolve this problem by the study of another movie obtained almost simultaneously of the same region on the sun in the $H\alpha$ -line center through the other 10" telescope. High resolution $H\alpha$ -line center pictures show considerable fine structure all over the frame. Visual examination and photoelectric intensity measurements of the same region as those observed in the blue wing movies, show intensity oscillations but with considerable reduction in the amplitude of the brightness fluctuation in the plage region. But it was difficult to obtain one-to-one correlation in phase with the blue wing intensity oscillations. The central region of rosettes appear completely filled with $H\alpha$ -bright mottles and show oscillatory period in intensity on the order of 6 minutes on $H\alpha$ -line center movie also. Considering the results obtained from the study of the $H\alpha$ -line center and the blue wing movies we could not separate from the observed intensity oscillation the effect due to the Doppler shift and due to intrinsic brightness variation.

It has been shown by Noyes and Leighton (1963), Evans, et al. (1963), Howard, et al. (1968) and many other authors that the

oscillatory period of the velocity field decreases with height in the solar atmosphere. The period is found to decrease from 300 sec at the photospheric level to about 200 sec at the chromospheric level. Comparing the observed periods of intensity oscillations in $H\alpha$ -0.5A in the supergranulation network, at the centers of rosettes and in plage granules, we see that the period of oscillation inside the network (170 ± 44 sec) is definitely less than the period in the rosette center (312 ± 56 sec) and that in plage granules (282 ± 49 sec). Since the height of formation of $H\alpha$ -0.5A is nearly the same in all these regions, the observed difference in oscillatory period would be mainly due to the variation in the physical conditions in the two regions at the same height.

It has been well established (Frazier, 1968) that at the vertices of supergranulation networks, where rosettes are located, the magnetic field strength is much higher than inside the network and also in plages the field is higher compared to the non-plage regions. It seems plausible to attribute the observed difference in period as due to the difference of magnetic field strength in the two regions. At the photospheric level, however, it is found by Howard (1967) that the oscillatory period of velocity field does not depend on the field strength in the region. Jensen and Orrall (1963) found from the study of intensity fluctuation in K-line that the K_3 shows period on the order of 170 seconds while the K_{2V} and K_{2R} show periods on the order of 250 seconds. These two periods could be due to either actual height differences in the solar atmosphere or due to structural differences emitting K_2 and K_3 lines or due to both effects.

Recent observations made by Elliott (1969) in quiet regions show that three peaks appear in the power spectra of velocity oscillations in $H\alpha$ line; one at 287 sec, a broad peak around 170 sec and third at 900 sec. Comparing with the K- spectroheliogram he showed that the power at 170 sec peak is maximum in the region where the K emission is least, that is, at the centers of the supergranulation network. The observed period of intensity oscillations measured inside the network, agrees fairly well with Elliott's velocity oscillations corresponding to 170 sec period but we could not find correlation with the other two peaks in his power spectra. Ramsay (1971) obtained Doppler time-lapse movies in $H\alpha$, from simultaneous pictures made in the blue and red wings. He reports conspicuous velocity fluctuation at the center of the supergranulation network. It seems likely that the observed intensity oscillations inside the network is related to the velocity oscillations.

It has been established by Howard, et al. (1968), Sheeley (1971) and Sheeley and Bhatnagar (1971), that the amplitude of the oscillatory velocity field in plages decreases considerably at the photospheric level. At the level of formation $H\alpha$ -0.5A also we may expect that the amplitude of the oscillatory velocity would be reduced in plage regions compared with that in weak field regions. However, our results clearly show conspicuous intensity oscillations in plage regions and in rosette centers, this suggests that the observed oscillations in higher magnetic field regions are mainly due to large scale intensity fluctuations, instead of velocity variations. It would be of great interest to measure simultaneously the velocity and intensity variations in $H\alpha$ -fine structures seen

seen on H α -high resolution filtergram movies.

5. CONCLUSION

From the intensity measurements on the time-lapse movies made in the blue wing of H α and in line center, we arrive at the following conclusions:

(1). Conspicuous periodic intensity oscillations inside supergranulation have been observed with period on the order of 170 ± 44 sec.

(2). Intensity oscillations in rosette centers and in plage granules have been found with period on the order of 312 ± 56 and 282 ± 49 seconds respectively.

(3). The sunspot umbra shows (well defined) periodic oscillations in intensity.

(4). The visibility of fine dark mottles in rosettes seems to be correlated with the brightness oscillations at the rosette center, and it is suggested that the observed intensity oscillations may be responsible for shooting out the dark mottles from the rosettes.

(5). Intensity oscillation can be measured on films, which makes available a large amount of existing data for study.

Acknowledgements

We wish to thank Dr. Harold Zirin for his interest and encouragement in this project. One of us (AB) is grateful to Dr. N. R. Sheeley of the Kitt Peak National Observatory for discussing the technique of intensity measurement directly from the 16mm movies. The research was funded by NSF Grant No. GA 24015 and NASA Grant No. 05002071.

REFERENCES

- Beckers, J.M. :1968, Sol. Physics, 3, 367.
- Beckers J.M. and Tallant, P.E.:1969, Sol Physics, 7, 351.
- Bhatnagar, A.:1971, Sol. Physics, 18, 40.
- Bray, R.J.:1968, Sol. Physics, 5, 323.
- Elliott, I.:1969, Sol. Physics, 6, 28.
- Evans, J.W., Michard, R. and Servajean, J.:1963, Ann. Astrophysics, 26, 368.
- Foukal, P.:1971, Sol. Physics, in press.
- Frazier, E.D.:1970, Sol. Physics, 14, 89.
- Howard, R.F., Tanenbaum, A.S., and Wilcox, J.M.:1968, Sol. Physics, 4, 286.
- Jensen, E. and Orrall, F.Q.:1963, Astrophys. J., 138, 252.
- Macris, C.J. and Alissandrakis, C.E.: 1970, Sol. Physics, 11, 59.
- Noyes, R.W. and Leighton, R.B.:1963, Astrophys. J., 138, 631.
- Parker, E.N.: 1964, Astrophys. J., 140, 1170.
- Ramsay, H.E.:1971, Private communication.
- Sheeley, N.R. and Bhatnagar, A.: 1971, Sol. Physics, 18, 195.
- Sheeley, N.R.: 1970, in R. Howard (ed.), "Solar Magnetic Fields", IAU Symp., 43.
- Zirin, H.: 1970, Sky and Telescope, 39, 215.
- Zirin, H.: 1971, Sol. Physics, in press.

CAPTIONS

Figure 1. Filtergram obtained at 18 h 28 m 48 S.U.T. at

$H\alpha$ -0.5A. The letters indicate the location where the intensity oscillations were measured. (Observers: Bhatnagar and Klemroth)

Figure 2. Intensity-time recordings made in (a) blank region as shown in Figure 1, showing no brightness fluctuation in the region, in (b)~(f) inside $H\alpha$ -network.

Figure 3. Intensity-time recordings made in the centers at rosettes of (A) to (D) in Figure 1.

Figure 4. Intensity-time recordings made in plage regions. Measured positions are shown in Figure 1.

Figure 5. Intensity-time recording in umbra (U).

Figure 6. Time sequence $H\alpha$ -0.5A filtergrams, showing "rosette" C.

Figure 7. Visibility-time plots of dark fine mottles in rosette C, the numbers from 1 through 8 indicate the corresponding mottles seen in Figure 6. Top curve shows the intensity oscillations at the center of the rosette.

NOT REPRODUCIBLE

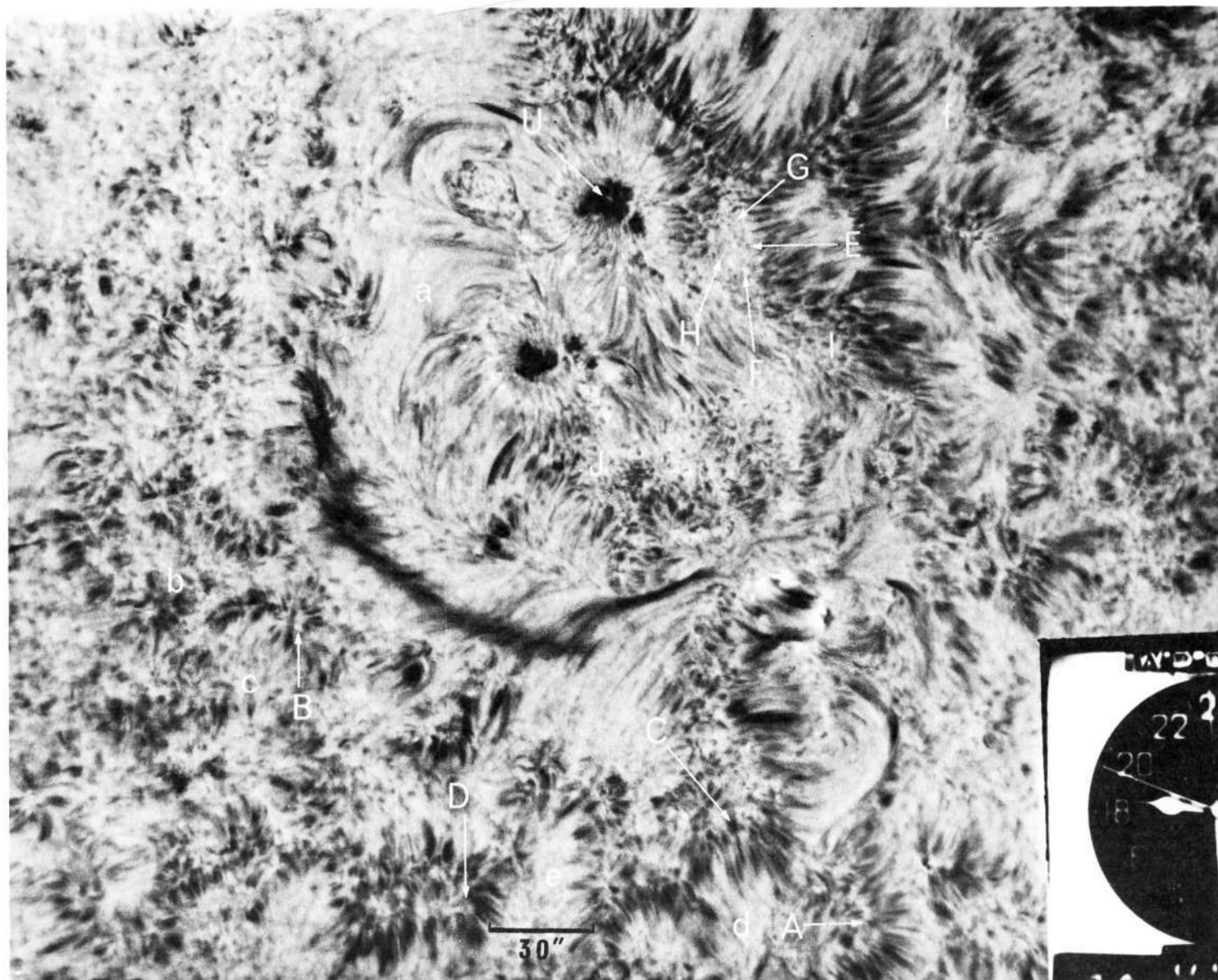


Fig. 1

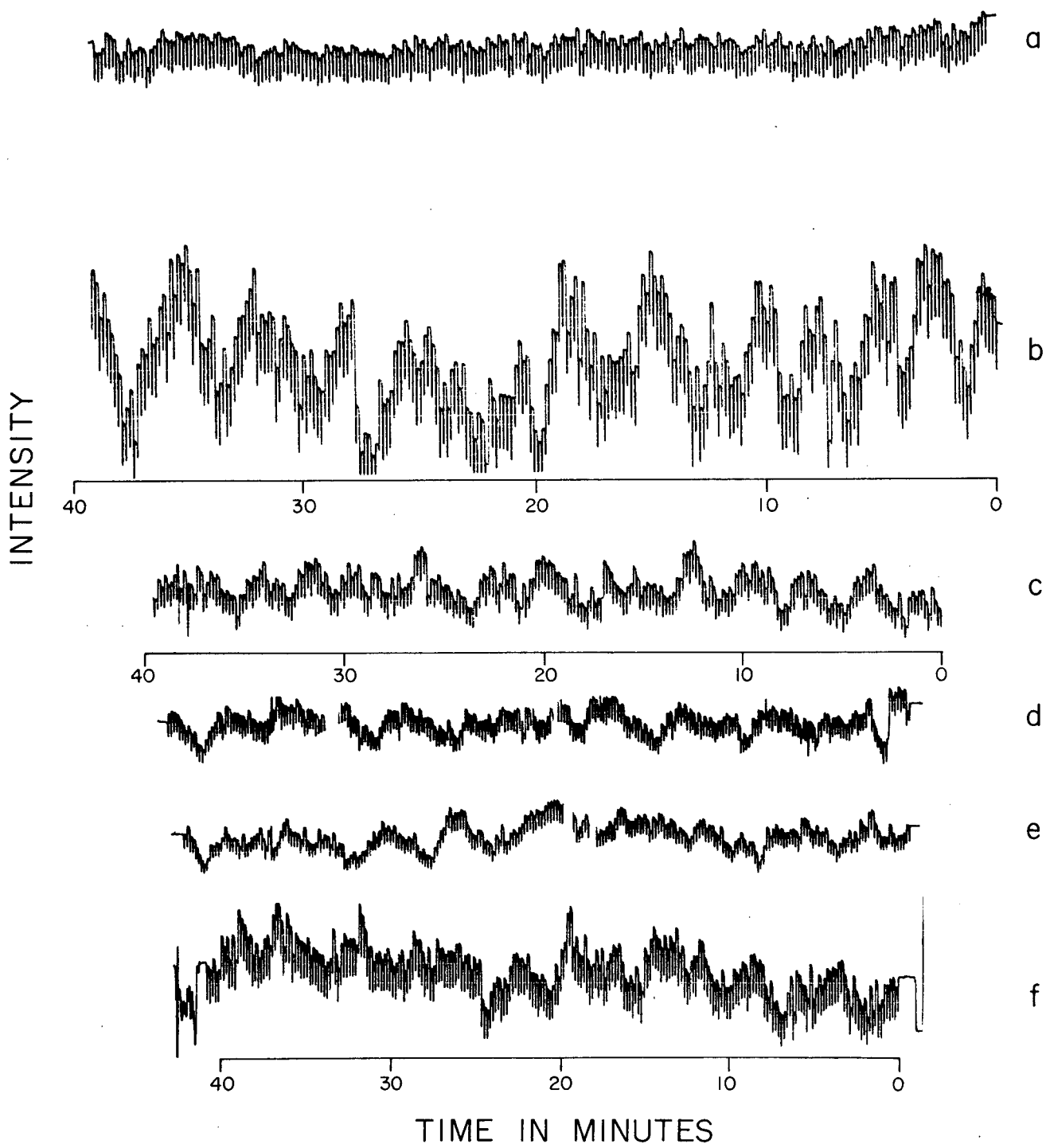


Fig. 2

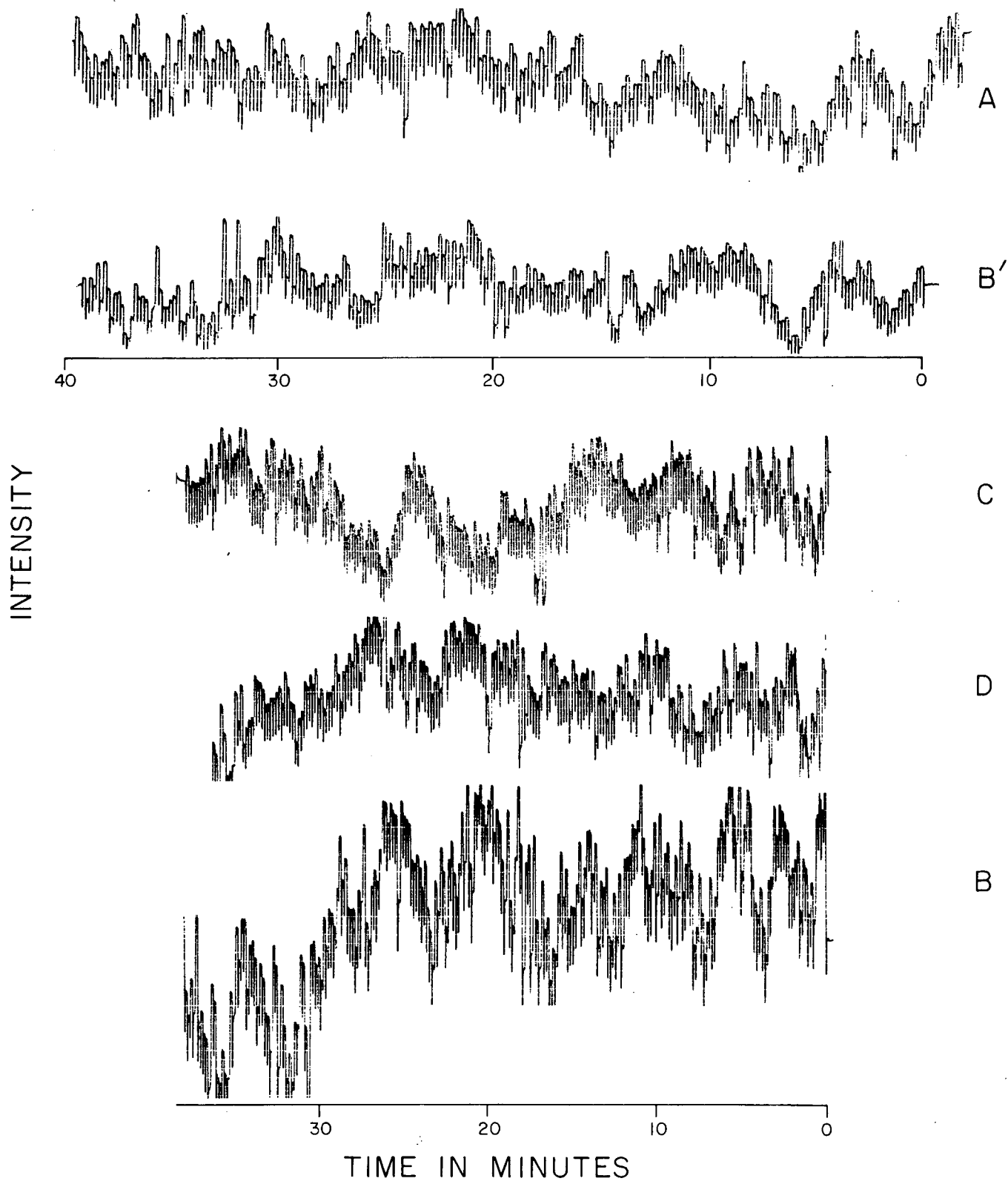


Fig. 3

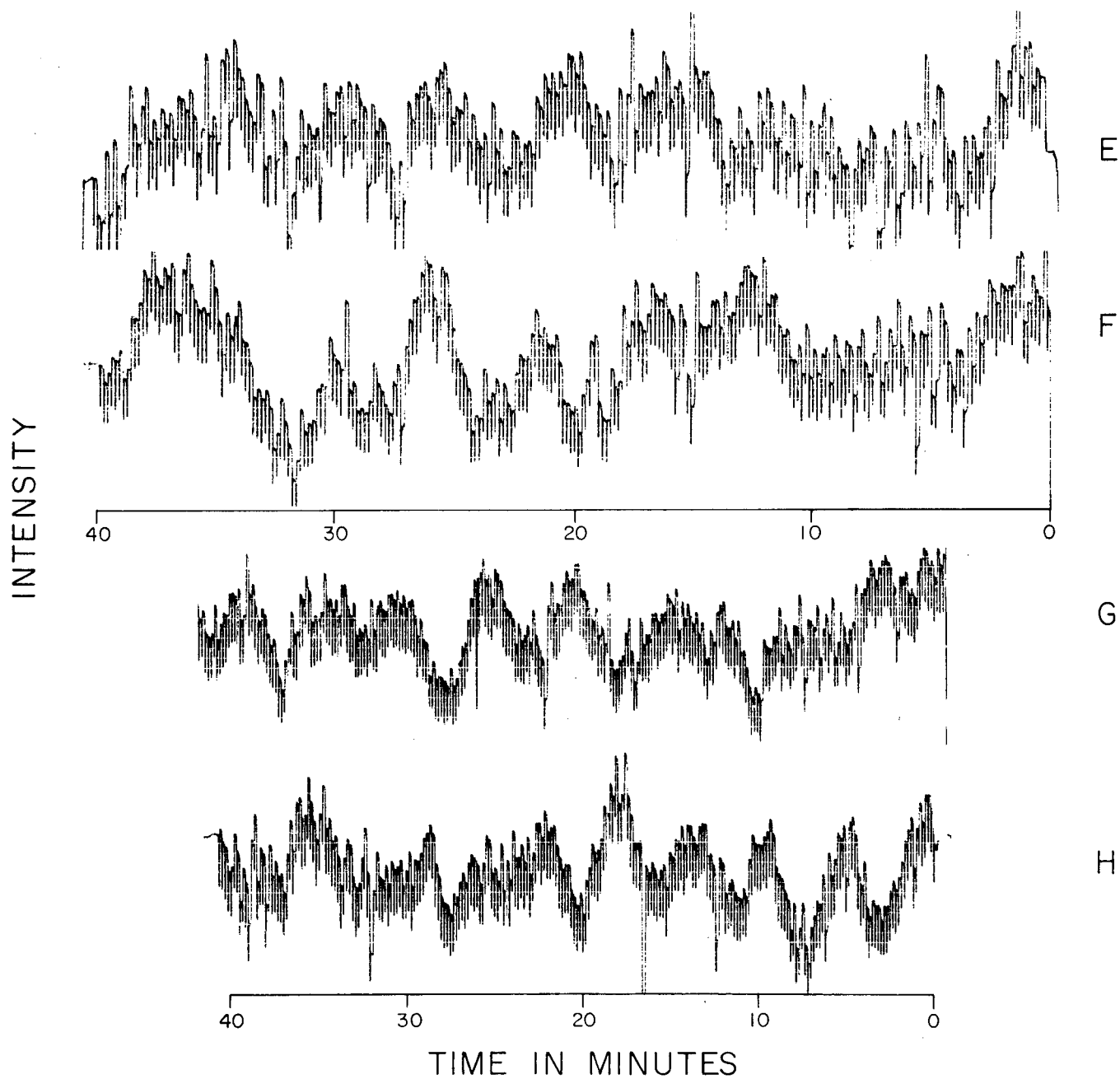


Fig.4

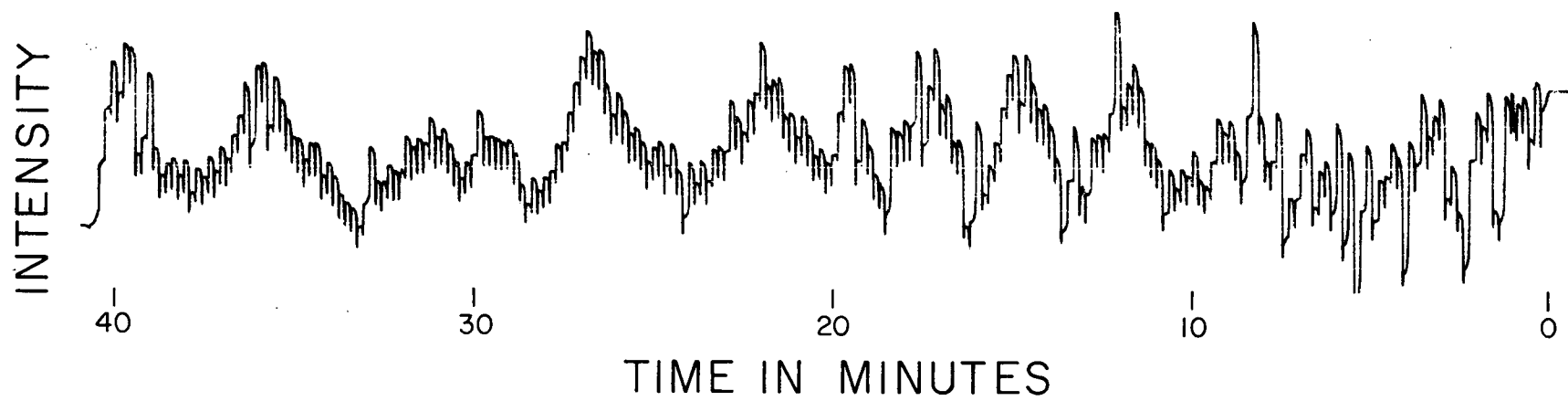
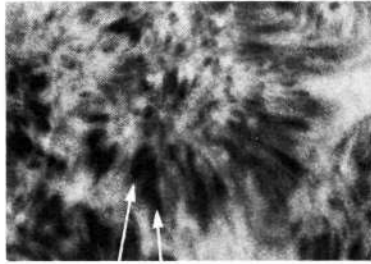


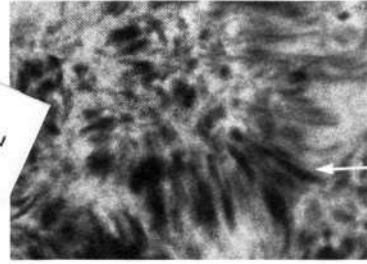
Fig. 5

18.10. 50 UT



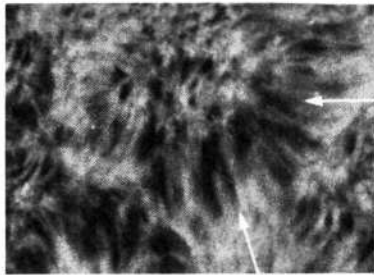
51

18.13. 50 UT



3

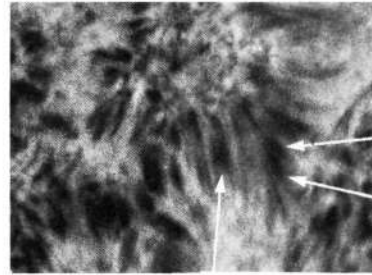
18.19. 30 UT



4

2

18.34. 20 UT



6

7

8

NOT REPRODUCIBLE

Fig. 6

